UAF-Frontier Snowfall/Blowing Snow Observations at CMDL, Barrow: Preliminary Result for 2001

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BACKGROUND

Systematic errors caused by wind-induced undercatch, wetting, and evaporation losses in precipitation measurement have long been recognized as affecting all types of precipitation gauges. The need to correct these biases, especially for solid precipitation measurement, has now been more widely acknowledged, as the magnitude of the errors and their variation among gauges have become known and their potential effects on regional, national, and global climatological, hydrological, and climate change studies have been recognized.

To assess the national methods of measuring solid precipitation, the World Meteorological Organization (WMO) initiated the Solid Precipitation Measurement Intercomparison Project in 1985. Thirteen countries participated in this project, and the experiments were conducted at 20 selected sites in these countries from 1986 to 1993. Methods of bias correction have been developed for many national precipitation gauges commonly used in the northern hemisphere [*Yang et al.,* 1995, 1998a, 1999, 2000; *Goodison et al.*, 1998]. Test implementations of the WMO correction procedures have been made to the archived precipitation data in some regions/countries [*Metcalfe and Goodison*, 1993; *Førland et al*., 1996; *Yang et al.*, 1998b]. The bias corrections have increased the winter and annual precipitation amounts by up to 50-100% in the high-latitude regions. These results clearly show that precipitation amounts in these regions are much higher than previously reported. This points to a need to review our understanding of freshwater balance and the assessment of atmospheric model performance in the Arctic regions.

The Arctic climate is characterized by low temperature, generally low precipitation, and high winds. Arctic precipitation events generally produce small amounts, but they occur frequently and often with blowing snow. Because of the special conditions in the Arctic, the systematic errors of gauge-measured precipitation and factors such as wind-induced undercatch, evaporation, and wetting losses, underestimates caused by not accounting for trace amounts of precipitation and over/under measurement because of blowing snow are enhanced and need special attention. This issue has been a consideration in World Climate Research Program (WCRP) projects. For instance, the WCRP/Arctic Climate System Study (ACSYS) program concludes that correction of gauge precipitation observations is a major issue with respect to solid precipitation in the polar regions and that this issue is particularly relevant to studies of the freshwater cycle in the Arctic region being undertaken in ACSYS and Global Energy and Water Cycle Experiment (GEWEX) projects, such as the GEWEX Asian Monsoon Experiment (GAME)-Siberia [*Yang and Ohata*, 2001] and the Mackenzie Basin GEWEX Study (MAGS).

The review of the WMO Intercomparison results by the WCRP/ACSYS project concluded that although the results of the WMO Solid Precipitation Measurement Intercomparison have not been fully tested in Arctic conditions, the general principles and the results from the WMO project can serve as a guide for developing correction procedures for Arctic precipitation data. It is recommended that an intercomparison experiment be conducted to further test the national precipitation gauges commonly used in Arctic regions and to evaluate the existing bias correction procedures.

Recognizing the importance of the precipitation data quality to cold-region hydrological and climatic investigations, the Japan Frontier Research System for Global Change and the Water and Environmental Research Center (WERC), University of Alaska, Fairbanks (UAF), have collaboratively undertaken a gauge intercomparison experiment and blowing/drifting snow observation study at the Barrow, Alaska, CMDL research laboratory. The goals of this research are to (1) review the existing bias-correction procedures that have been developed in gauge intercomparison experiments and that may be suitable for high latitude regions; and (2) test and evaluate the applicability of the WMO bias-correction methods in polar regions of high winds with blowing/drifting snow conditions.

SITE AND INSTRUMENTATION

This study was carried out at the CMDL Barrow site. In February and September 2001, several precipitation gauges were installed for intercomparison. These include reference gauges and various national standard gauges commonly used in the Arctic regions:

- Double fence intercomparison reference (DFIR) at 2.5 m; WMO reference (Figure 1).
- Wyoming snow fence system at 2.5 m; U.S. reference gauge for snowfall observations (Figure 2).
- NOAA-ETI gauge at 1 m.
- Hellmann gauge at 2 m; standard gauge for Greenland, Denmark, and Germany.

Fig. 1. WMO double fence intercomparison reference (DFIR).

Fi.g. 2. U.S. Wyoming snow fence.

- Russian Tretyakov gauge at 2 m; Russian standard gauge, also used in Mongolia and other countries.
- U.S. National Weather Service (NWS) 8-in (20-cm) nonrecording gauge at 2 m; U.S. standard gauge, widely used in other countries.

An automatic weather station for blowing/drifting snow observations in winter months was set up to investigate blowing snow mass fluxes as functions of wind speed, air temperature, and height, and to evaluate their impact on gauge snowfall observations.

DATA ANALYSIS AND PRELIMINARY RESULTS

Data analysis follows the guidelines established in the WMO Solid Precipitation Measurement Intercomparison Project, with a focus on defining mean catch ratio of gauges and the relation of gauge catch as a function of wind speed and air temperature.

Up to December 2001, 31 precipitation events, i.e., 3 rainfall cases and 28 snowfall cases, have been collected. The event total precipitation amounts measured range from trace (when the gauges registered zero amount of precipitation) up to 40 mm. These event data sometimes were the total accumulation of several precipitation events, because the gauges were emptied irregularly. The data also include a few cases of blowing-snow events during high wind conditions.

Preliminary analysis of collected data shows that the mean catches of the gauges relative to the DFIR for snowfall observations were about 90% for the Wyoming snow fence, 59% for the Tretyakov gauge, 24% for the U.S. 8-in gauge, and 27% for the Hellmann gauge (Figure 3). These mean catches are close to the results for similar testing environments of the WMO gauge intercomparison experiments. For instance, the catch ratios of the Wyoming fence to the DFIR were 89% and 87% at Regina and Valdai, respectively. The mean catch of snowfall for the U.S. 8-in gauge at Valdai was 44% [*Yang et al.*, 1998a]. For the Tretyakov and Hellmann gauges, the mean catch of snowfall was reported to be 63-65% and 43-50%, respectively, at the northern test sites of the WMO experiment [*Yang et al.*, 1995, 1999].

FUTURE WORK

Continued intercomparison data need to be collected at Barrow in the next few winter seasons. A comprehensive data set will enable us to carry out (1) compatible analysis with the WMO intercomparison data sets, (2) analysis of the catch ratio versus wind speed/temperature, and (3) assessment of the applicability of the WMO methods and results in the Arctic regions. In addition, the impact of blowing/drifting snow on gauge catch is another issue that needs research attention. We will develop procedures to quantify the flux of blowing snow into a snow gauge and evaluate the impact of blowing/drifting snow to bias correction of gauge-measured snowfall data in the polar regions. This work will also generate bias-corrected precipitation data sets and climatology for Barrow and northern Alaska, including seasonal/annual regional precipitation maps.

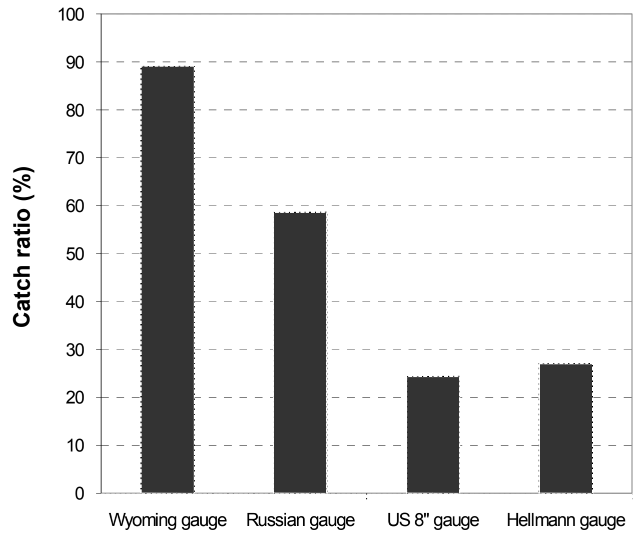

Fig. 3. Mean catch ratio of four gauges versus the DFIR, Barrow.

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